

Supporting information

NiCo₂O₄ Arrays with tailored morphology as Hole Transport Layers of Perovskite Solar Cells

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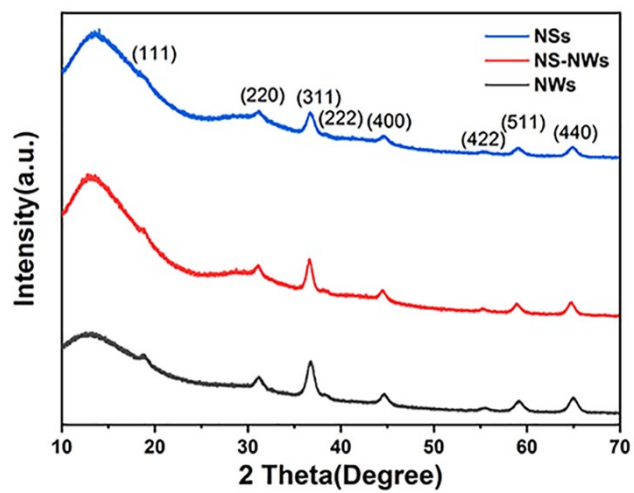


Figure S1. The XRD patterns of NiCo₂O₄ NSs, NW-NWs and NWs.

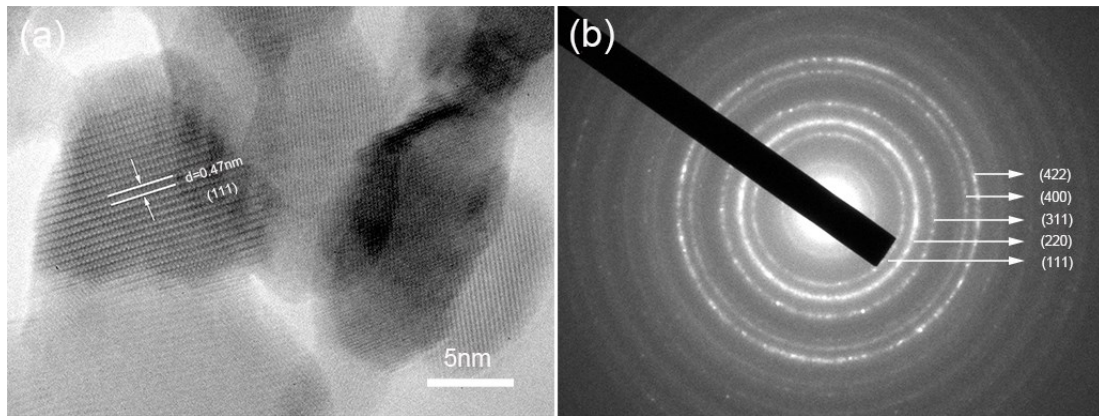


Figure S2. (a) The HRTEM; (b) SEAD pattern of NiCo₂O₄ NWs.

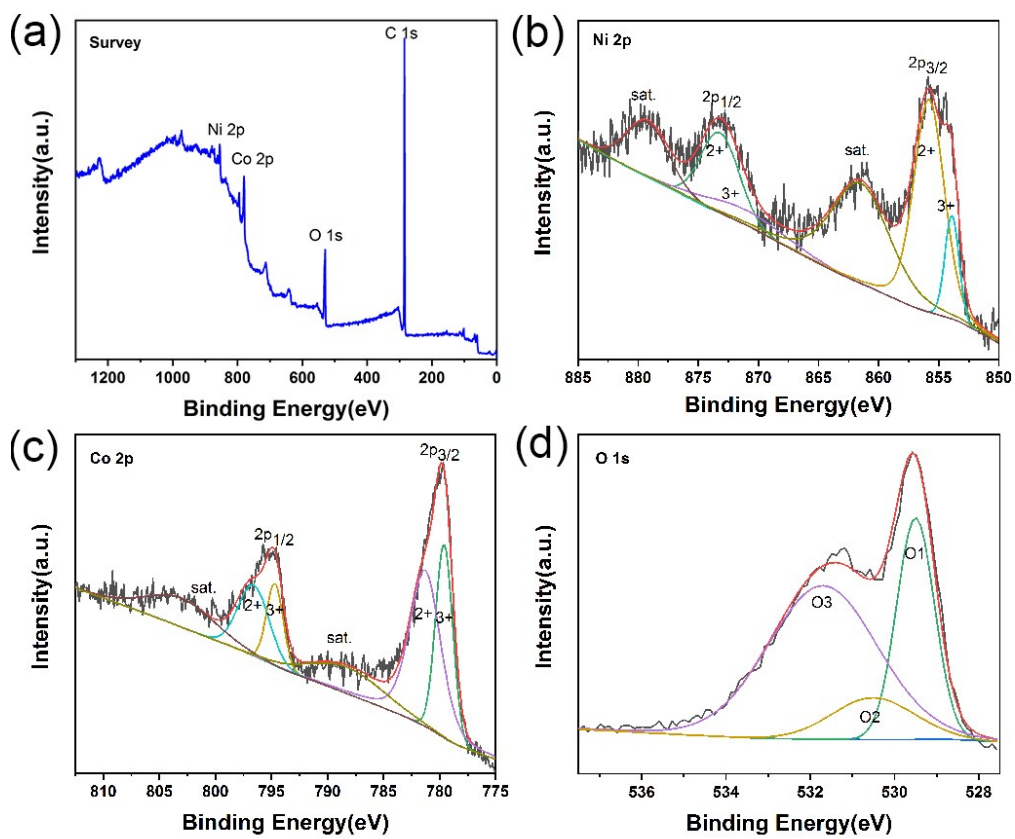


Figure S3. The XPS spectra of NiCo₂O₄ NWs: (a) XPS full spectra, (b) Ni 2p, (c) Co 2p, (d) O1s.

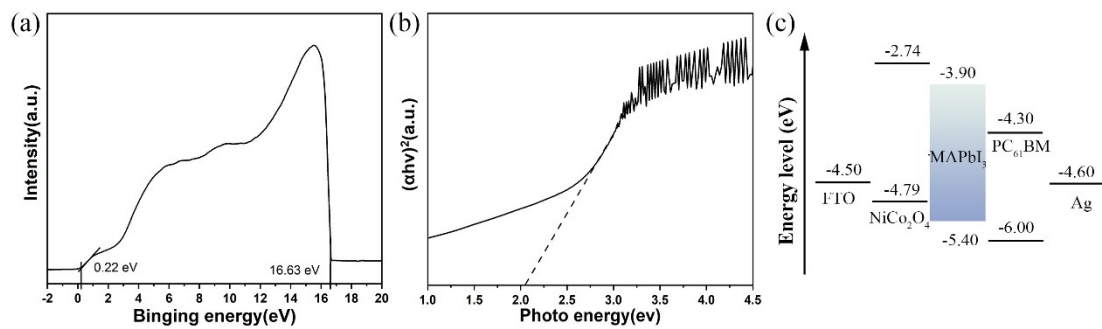


Figure S4. (a) The UPS spectra of NiCo₂O₄ NWs; (b) Tauc plot of the absorption spectra; and (c) The energy diagram of the used materials.

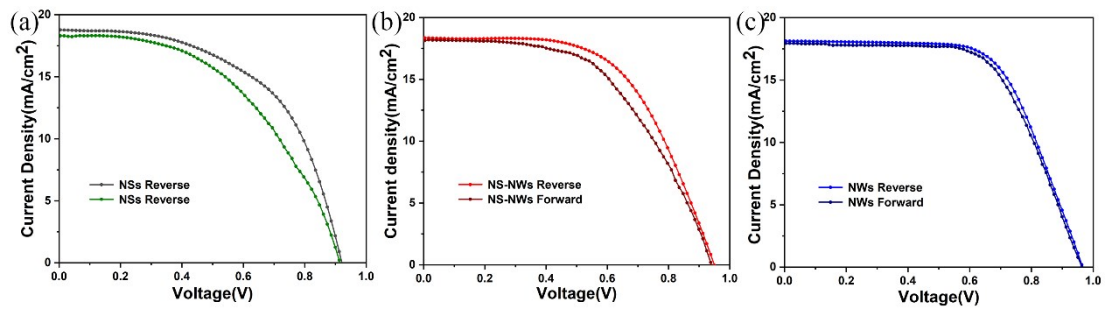


Figure S5. The reverse and forward scan J-V curves: (a) NSs, (b) NS-NWs, (c) NWs.

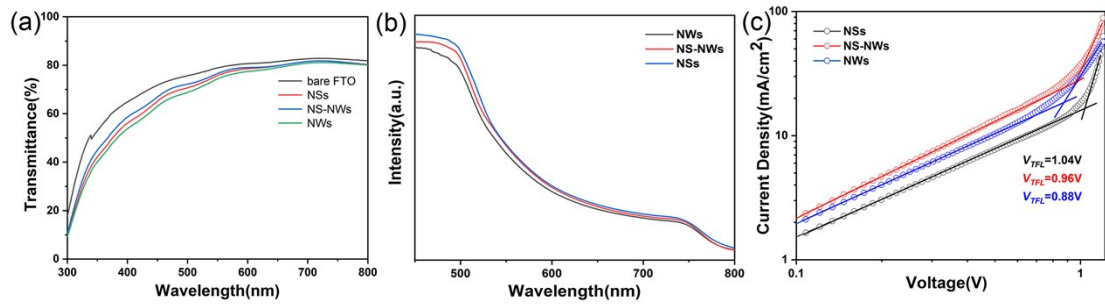


Figure S6. (a) Optical transmittance spectrum of bare FTO/glass and NiCo₂O₄ NSs, NS-NWs and NWs films grown on FTO/glass substrate; (b) UV-vis absorption spectra of perovskite films based on NiCo₂O₄ NSs, NS-NWs and NWs respectively; (c) Dark J-V curves of hole-only device with structure of FTO/NiCo₂O₄/MAPbI₃/spiro-OMeTAD/Ag.

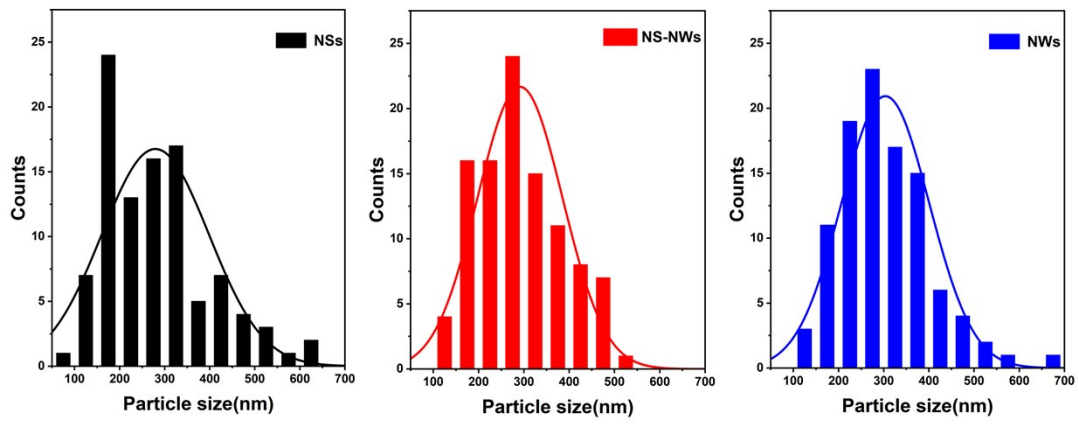


Figure S7. The particle size distribution of perovskite film based on different NiCo_2O_4 film layer.

Table S1. Photovoltaic parameters of NSs, NS-NWs and NWs based devices in different scan directions.

Device	Scan direction	J_{sc} (mA/cm^2)	V_{oc} (V)	FF (%)	PCE	Hysteresis index(%)
NSs	Reverse	18.80	0.92	55.04	9.52	13.97
	Forward	18.31	0.91	49.15	8.19	
NS-NWs	Reverse	18.34	0.94	58.62	10.11	9.79
	Forward	18.15	0.93	54.03	9.12	
NWs	Reverse	18.13	0.97	65.87	11.58	6.56
	Forward	17.95	0.97	62.14	10.82	

Table S2. Lifetime parameters of TRPL spectra of NSs, NS-NWs and NWs devices.

Device	$A_1(\%)$	$\tau_1(ns)$	$A_2(\%)$	$\tau_2(ns)$	$\tau_{avg}(ns)$
NSs	61.75	24.6	38.25	83.57	64.57
NS-NWs	63.26	16.06	36.74	60.52	46.53
NWs	65.91	11.9	34.09	48.07	36.36

Table S3. EIS parameters of NSs, NS-NWs and NWs devices.

Device	$R_s (\Omega)$	$R_{ct} (\Omega)$
NSs	19.5	825.4
NS-NWs	19.3	1102.2
NWs	17.3	1623.6